THE UNIVERSITY of EDINBURGH
The Royal (Dick) School
of Veterinary Studies

Global Agriculture and
Food Systems

# The Future of Livestock in Global Food Systems

Symposium
2025

# Climate and livestock in Africa: future transitions

Philip Thornton

Global Agriculture & Food Systems Symposium:
The Future of Livestock in Global Food Systems
25 April 2025

# Outline

- Context
- Examples of early-stage transitions with climate, environmental & other benefits
- Rethinking African livestock & crop agriculture
- Concluding comments

# Livestock in Africa: current context


## Food demand rising rapidly

- Population growth: 1.5 B in 2024 to 2.5 B in 2050

## Social-economic change

- Economic growth in Africa 2-5% per year, but big variations
- Urbanization: 35% in 2000, 60% by 2050 (80% of growth in cities)
- Youth: 1 B under 35 in 2020, 1.6 B working age pop (15-64) by 2050
- Diets are shifting, expectations are shifting

## Climate change

- Increased frequency of droughts, floods, crop failure, season failure, …
- Increasing impacts on human and livestock health and well-being, …
- Livestock produce 12–17% of GHGs ($CO_2$ / $N_2O$ / $CH_4$): latter a big concern: GWP, short lifetime

## Land use

- Fragmentation: small holding sizes, constrained movement
- Arable land expanded by 30% in last 20 years, but environmental costs often high

# Whither the African livestock sector?

- Dairy consumption significantly increasing (8-10% per annum in places), driven by population growth and increased consumption per person
- Meat consumption per person also rising, particularly poultry (and pork) consumption
- Other than dairy in highland production systems of E Africa, livestock productivity in SSA remains low, with animal number increases fueling production growth
- Possibilities for the smallholder dairy sector to sustainably intensify (large yield gaps, growing demand), but land fragmentation and feed scarcity may affect its viability
- Small-scale dairy, pig, poultry production will continue to be key for local food security but may decline in importance as economies grow and conditions increasingly favour industrialised production

→ ***Future role of small-scale & extensive livestock production is highly uncertain***

Herrero et al. (2023)

# 1 Insect farming for fish and poultry feed in Kenya


*Benefits:* *Overcoming seasonal shortages of high-quality feed*
*Reduce competition for land*
*Job creation*

- Conversion of organic waste into protein and fats
- Potential value for insect livestock feed in Kenya estimated at USD 700 million annually
- Replacing 5% conventional protein in poultry feed with black soldier fly larvae worth > USD 100 million annually
- Already 1300 insect farmers in Kenya, with GoK support

*Further action:* *Raising awareness*
*Sourcing and utilising reliable food loss / waste streams as a feed for insects*
*Strengthen the regulatory environment*

# 2 Aquaponics in coastal Ghana

*Benefits:* *Raising domestic production, reducing import dependency*
*Job creation*

- A circular system combining aquaculture (often *Tilapia*), hydroponics (leafy crops) and microbes that turn fish waste to plant nutrients
- Utilizes less water and land, well-suited to urban / periurban environments
- Feed fish with plants like duckweed, meal, insects
- Aquaculture sector growing fast to better meet domestic demand, aquaponics can be highly profitable and empowering for women farmers


Lawrencia Kwansah

*Further action:* *Raising awareness and knowhow*
*Need for government support*
*Better access to micro-finance*
*Better access to supplies (e.g. fingerlings)*

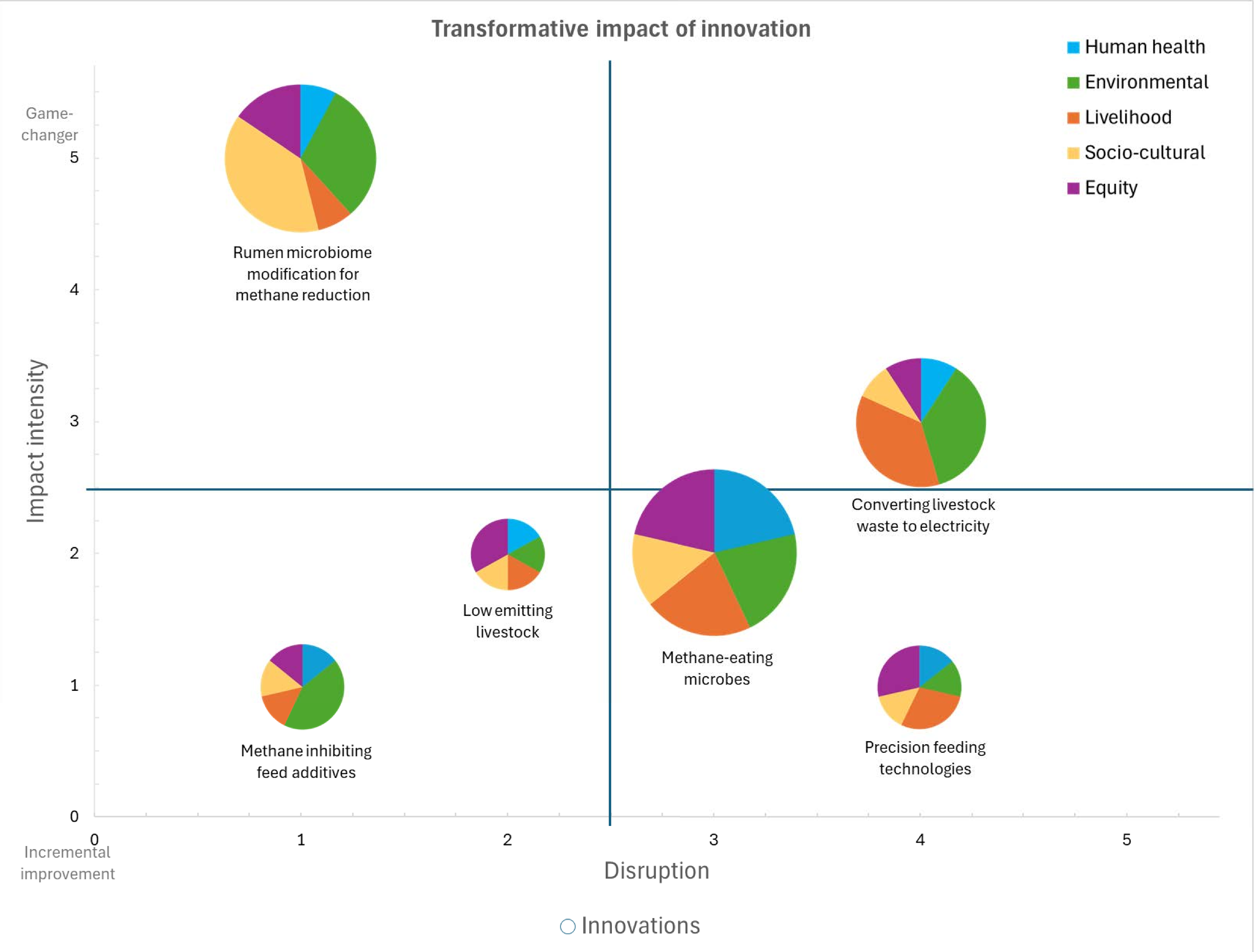
# 3 Agrivoltaic systems in the pastoral-agropastoral transition zones

*Benefits:* *Diversifying income streams*
*Helping livestock adapt to climate change*
*Job creation*

- Household income from electricity generation via solar panels as well as from feed / livestock production
- Shade-tolerant feed crops, shade provision for livestock
- Bundle with local electricity storage options (e.g. sand batteries)
- Some pilots in all regions of Africa, potential currently unknown

*Further action:* *Government to address land tenure uncertainties*
*Provision of appropriate finance mechanisms*
*New regulatory frameworks for energy investments, payments for surplus electricity*

# Some livestock-related technologies on the horizon




https://foodsystems.tech/
Figure: Saskia Doherty, Clim-Eat

# What could future livestock systems look like in Africa?

- Developing participatory collaborative visions of future food systems at different levels: local, national, regional
- Capacity development in methods and tools for participatory processes, visioning, foresight, addressing uncertainty
- National & local science-policy dialogue platforms
- Actions that fit within continental climate-resilient development strategies & action plans, Nationally Determined Contributions, National Adaptation Plans, county integrated development plans

# Localised modernity?

*Hybrid crop and livestock systems that mix traditional and modern foods and technologies in ways that match local needs*

**Indigenous and traditional African livestock and food crops**

- Nutritional benefits (nutrient density can be higher than in other foods)
- Environmental benefits (drought and heat tolerance, lower emissions, …)
- Social-cultural benefits (strengthening local identity)
- Economic benefits (livelihoods and income)

**Potential impacts**

- Freeing up / reducing pressure on land
- Reducing environmental footprints
- Producing food nearer to where it’s consumed
- Enhancing resilience

# Innovating for change:
# New models for public agricultural research for development

- **Promote multi- and trans-disciplinary science** approaches that take account of cross-sectoral interests (food, health, energy, …)

- **Swarm intelligence**
  - Self-organization in pursuit of a common vision
  - Rapid prototyping and testing, failing, and iteration

- **Transformation labs**
  - Collaborative environments where experimentation with new configurations of food systems can occur
  - Facilitated processes to support multi-stakeholder groups to address complex problems and bring about future changes

Pereira et al. (2018)

# Innovating for change:
# Meeting the costs & reaping the benefits of reorienting agriculture

- Benefits include increased food system resilience; human health, USD 1 trillion per year (FOLU 2021); reduced food loss and waste, USD 2.6 trillion per year (FAO 2021)

- Adaptation costs have grown through time:
    - USD 49–171 billion / year for agriculture, water, human health, coastal zones and infrastructure (Parry et al., 2009)
    - Adaptation investments for infrastructure 2–8 % of GDP: several trillion dollars / year (Rozenberg and Fay, 2019)

- Official development assistance from DAC countries in 2023, USD 223 billion. Food system reorientation may need 3-5 times that

- Filling the gap: increases in official development assistance, increased climate finance from the public and private sectors, levies and taxes, redirecting existing funding streams, …

# Concluding comments

- Reconfiguring livestock systems to be more resilient, sustainable, equitable: huge challenges
- Designing and implementing **market incentives** to help spread costs and risk
  - Supply-push / demand-pull mechanisms: advance market commitments (AMCs), patent buyouts, …
  - Subsidy realignment for climate action
- **Safeguarding** against undesirable effects
  - Develop & apply simpler tools for MRV and metrics for resilience / adaptation
  - Monitoring uptake of innovation and its impacts on equity, inclusion, gender
- **Building trust, embracing change**: promoting discourses, dialogues that facilitate action
- Multilateralism down, not yet out? Investigating new / different **financing mechanisms**
  - More public-private partnerships
  - Mixtures of public, private, philanthropic financing
- **Embracing localism**: how to effectively balance reach and impact



p.thornton@cgiar.org

THE UNIVERSITY of EDINBURGH
The Royal (Dick) School of Veterinary Studies

Global Agriculture and Food Systems

# The Future of Livestock in Global Food Systems

Symposium 2025

# Table Discussions

- Introduce yourselves
- Reflect on a new thing you learned, any surprises, any gaps?
- Agree on one or two high level questions for one of the speakers or for the whole panel

- Make sure someone captures some notes on the flipchart

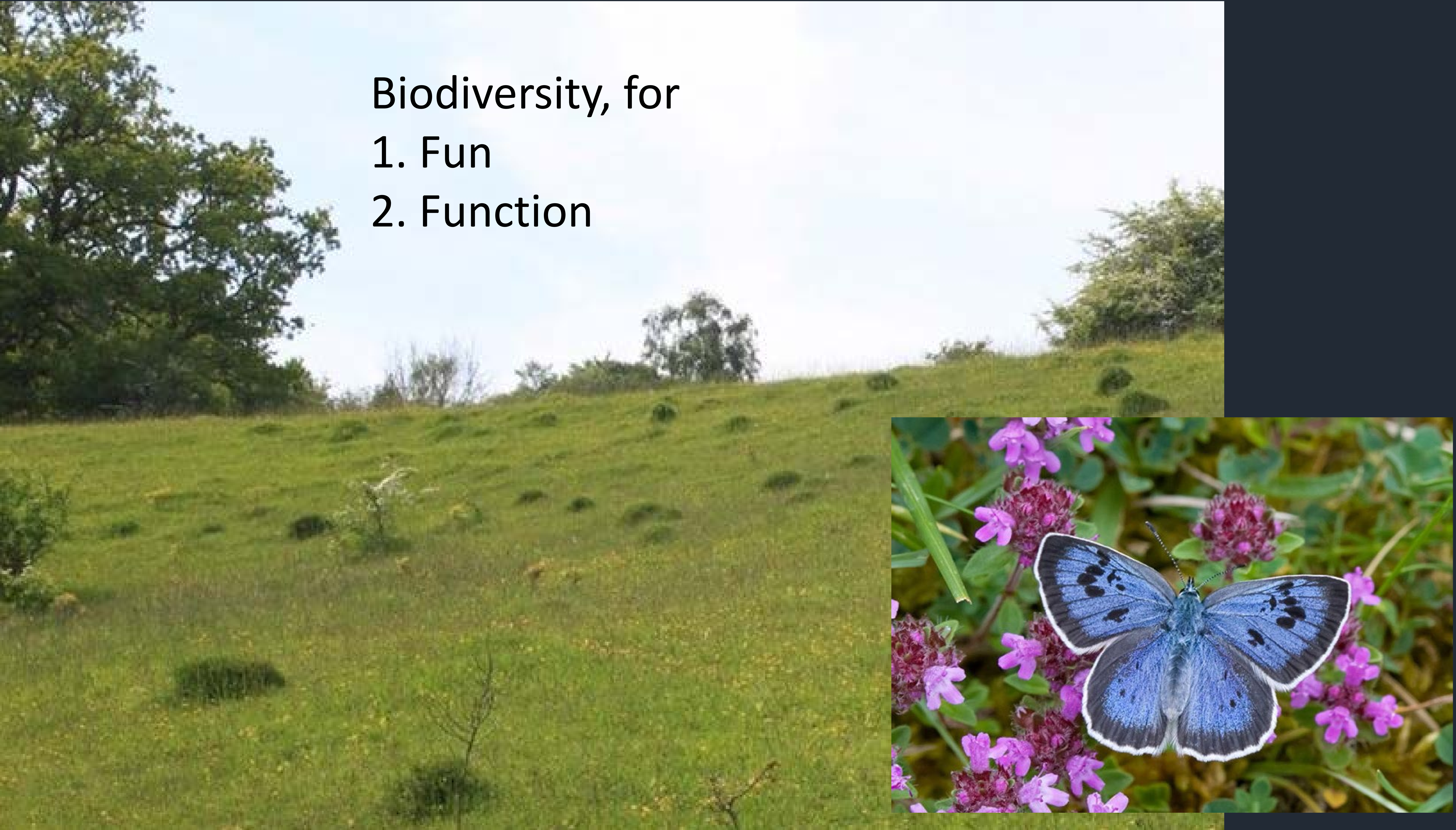
# How much livestock do we need to support biodiversity?

Alfy Gathorne-Hardy
University of Edinburgh

1. The large blue
2. Conceptual model
3. The answer to how much livestock we ‘need’

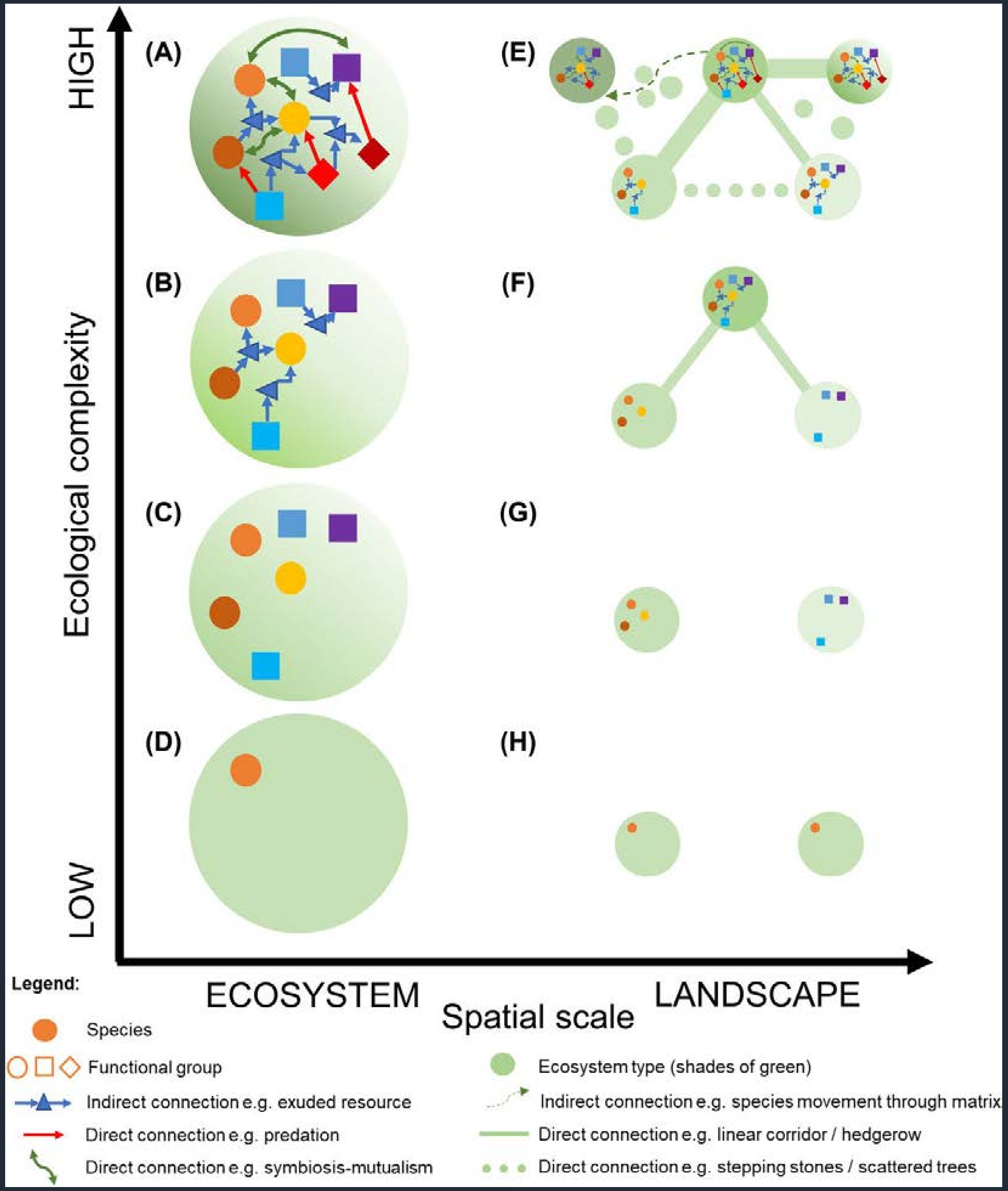
Biodiversity, for

1. Fun
2. Function



# Conceptual framework

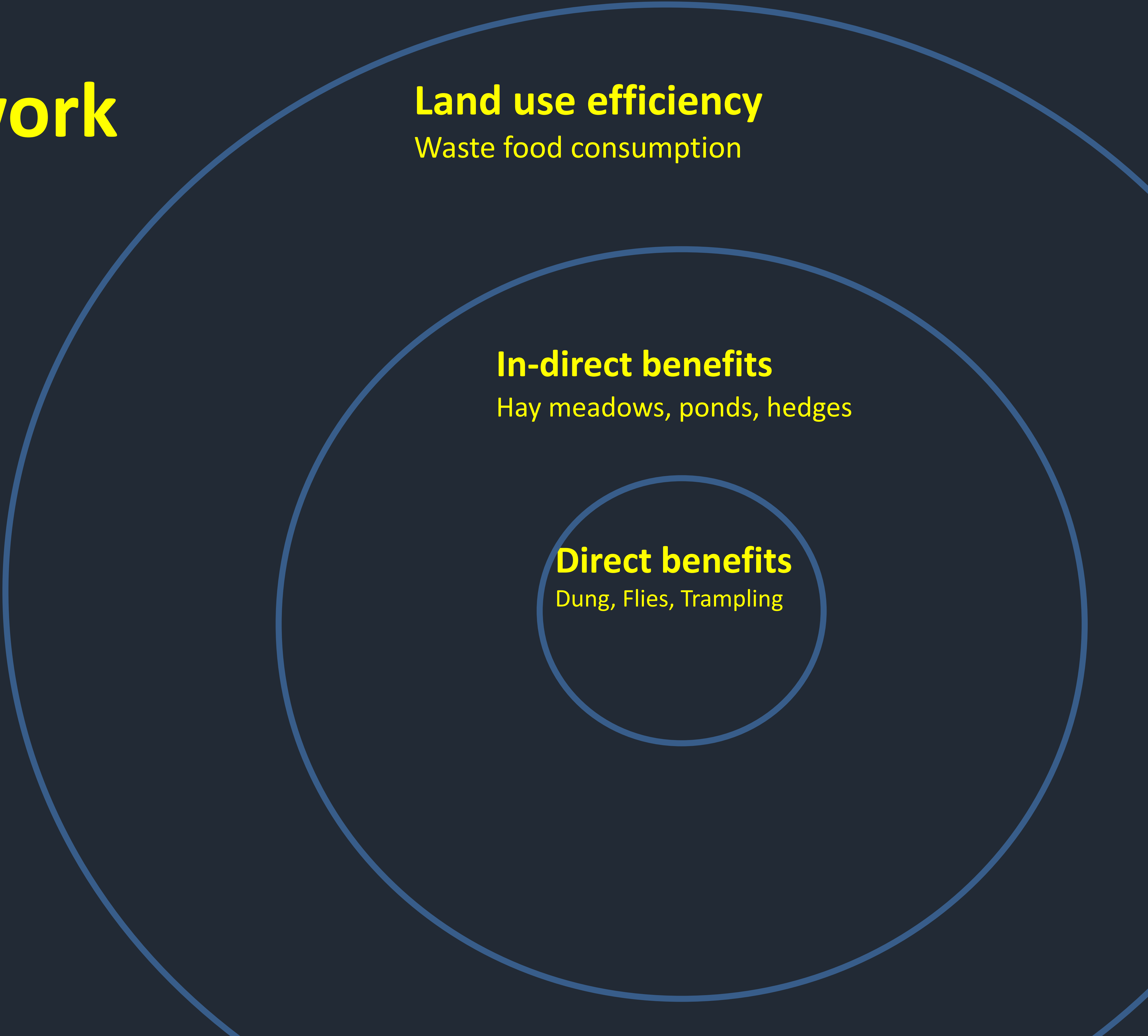
- No livestock at all unless demonstrated to benefit biodiversity
- What/ how much biodiversity do we need?
  - Cultural services
  - Regulating services
  - (Fun or Functional)




Bullock, J. M., et al. (2022). [Ecography **2022**(4).]

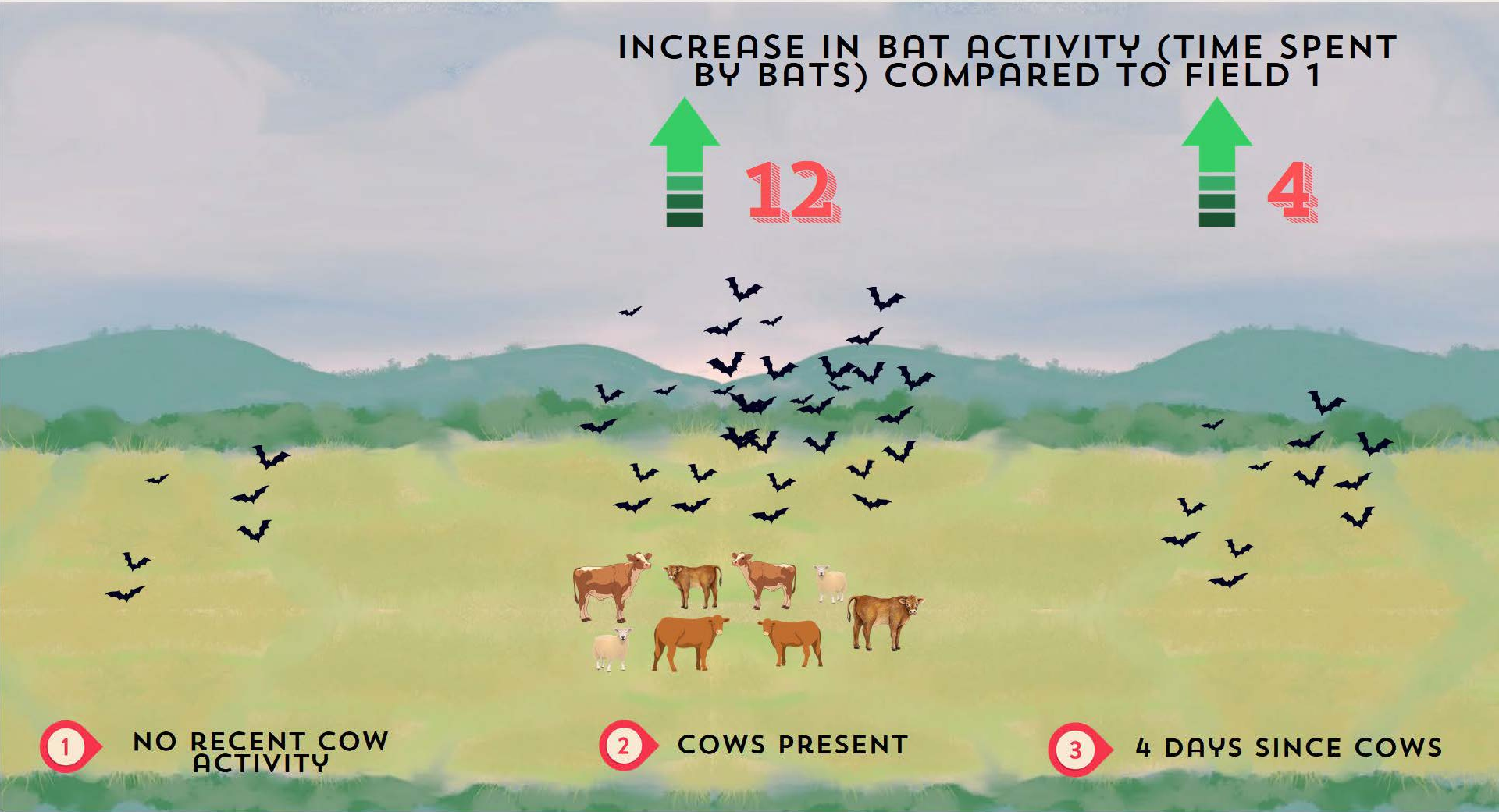
# Conceptual framework

- No livestock at all unless demonstrated to benefit biodiversity
- What/ how much biodiversity do we need?
  - Cultural services
  - Regulating services
  - (Fun or Functional)



**Direct benefits**

Dung, Flies, Trampling


INCREASE IN BAT ACTIVITY (TIME SPENT BY BATS) COMPARED TO FIELD 1
12
4
1
NO RECENT COW ACTIVITY
2
COWS PRESENT
3
4 DAYS SINCE COWS

# Direct benefit. Apex-ish predator
# Greater horseshoe bat (*Rhinolophus ferrumequinum*)

- **Massive population decline (>90%)**
- **Northern limit of range**
- Weight: 17g - 34g (AA battery)
- Life expectancy, up to 30 years
- Head & body length: 57mm - 71mm (pear)
- Forearm length: 54mm - 61mm
- Wingspan: 350mm - 400mm

# Cattle and greater horseshoe bats, a natural experiment

Loss of local cattle –

- reduced population of *Aphodius* dung beetles
- Population decline
- Juvenile growth "seriously harmed"
- Increased male births
- Starvation of juveniles


Ransome, R., and D. Priddis. 2005. The effects of FMD-induced mass livestock slaughter on greater horseshoe bats in the Forest of dean. English Nature.

# Land requirements to restore horseshoe bat populations

- To provide sufficient *Aphodius* to feed a colony of HSB every 30km, requires of **0.16%** of land:

| | Total area (ha) | Colonies | Area to cattle (ha) |
|---|---|---|---|
| Croppable land | 6,167,467 | 87 | 9,734 |
| Croppable and temp grass | 7,442,948 | 105 | 11,747 |
| All agric beyond rough grazing | 13,308,364 | 188 | 21,003 |

**Direct benefits**

Dung, Flies, Trampling

Fun: 5

Function: 2-5.

**In-direct benefits**

Hay meadows, ponds, hedges

**Direct benefits**

Dung, Flies, Trampling

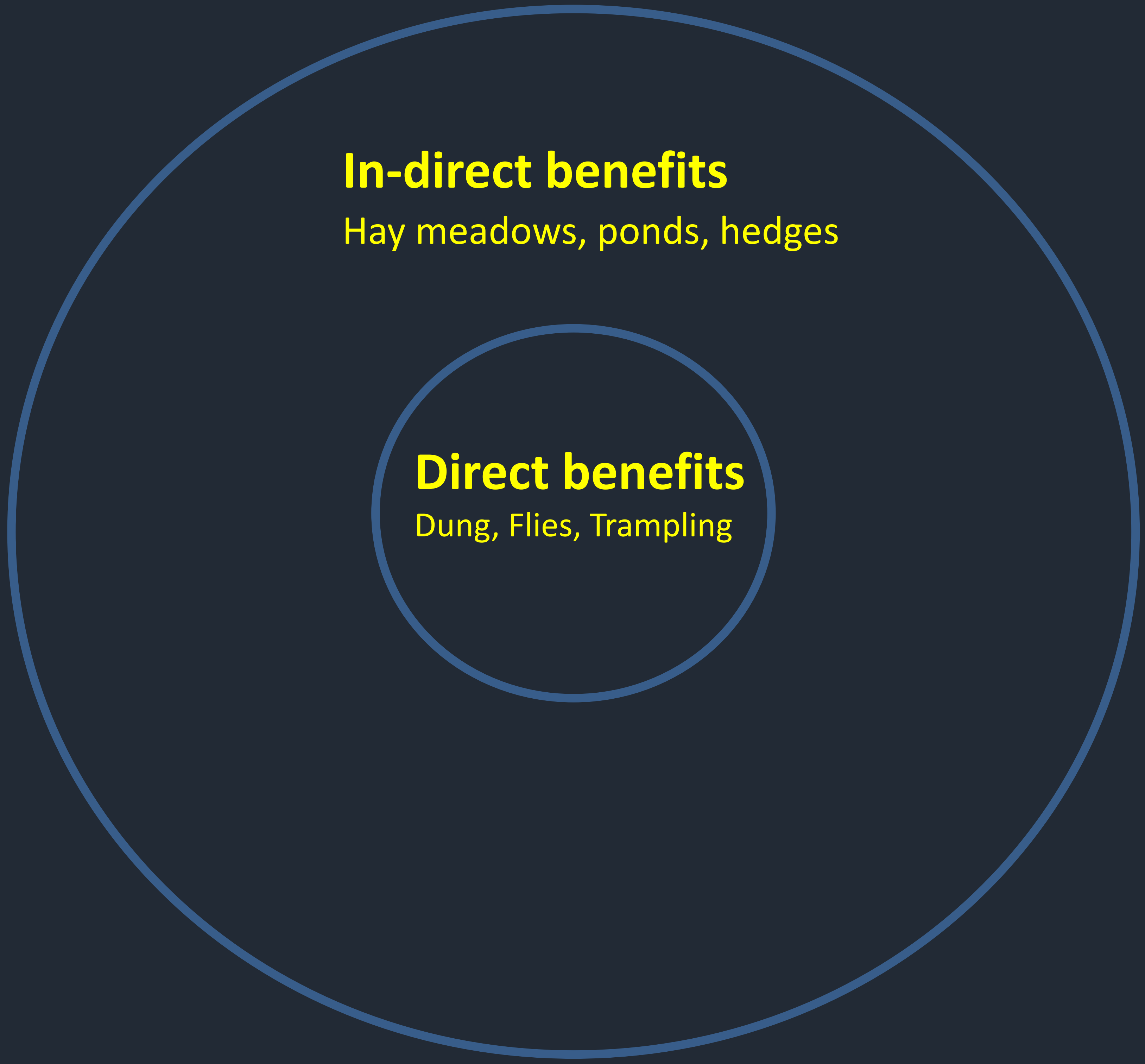
# In-direct benefits



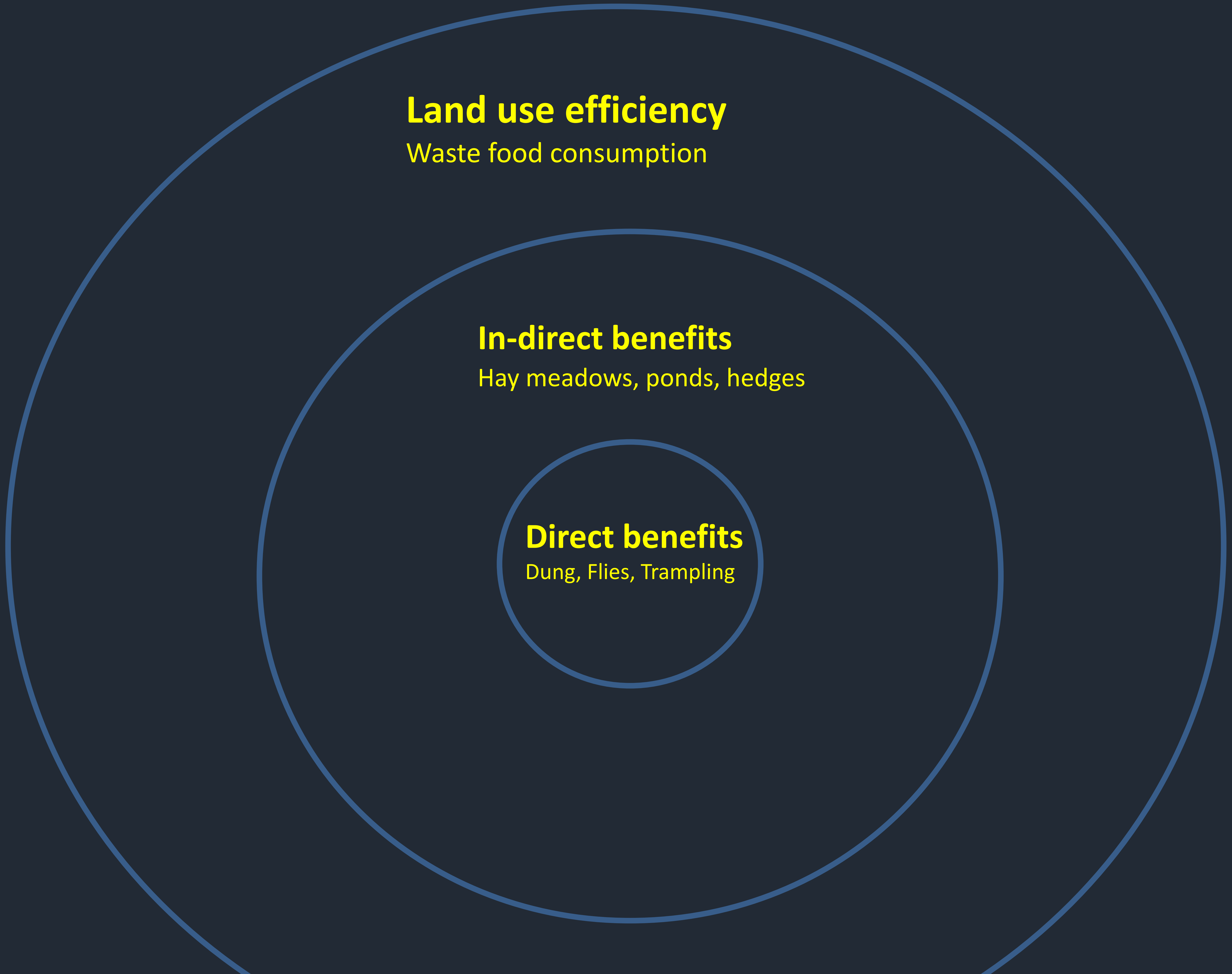
# In-direct benefits

- How much land down for conservation?
- 10%, so 5% of livestock?

| | Total area (ha) | Area to livestock (ha) |
|---|---|---|
| Croppable land | 6,167,467 | 308,373 |
| Croppable and temp grass | 7,442,948 | 372,147 |
| All agric beyond rough grazing | 13,308,364 | 665,418 |




Fun: 5
Function: 2-5.


Land use efficiency
Waste food consumption
In-direct benefits
Hay meadows, ponds, hedges
Direct benefits
Dung, Flies, Trampling

# Land use efficiency

1. Feeding people not pigs

- About 40% of arable is for livestock (based on wheat and barley). If we assume fed to pigs, using calories it achieves approx. 20% land use efficiency.

    ➔32% of arable land 'available'

2. Using 'waste':

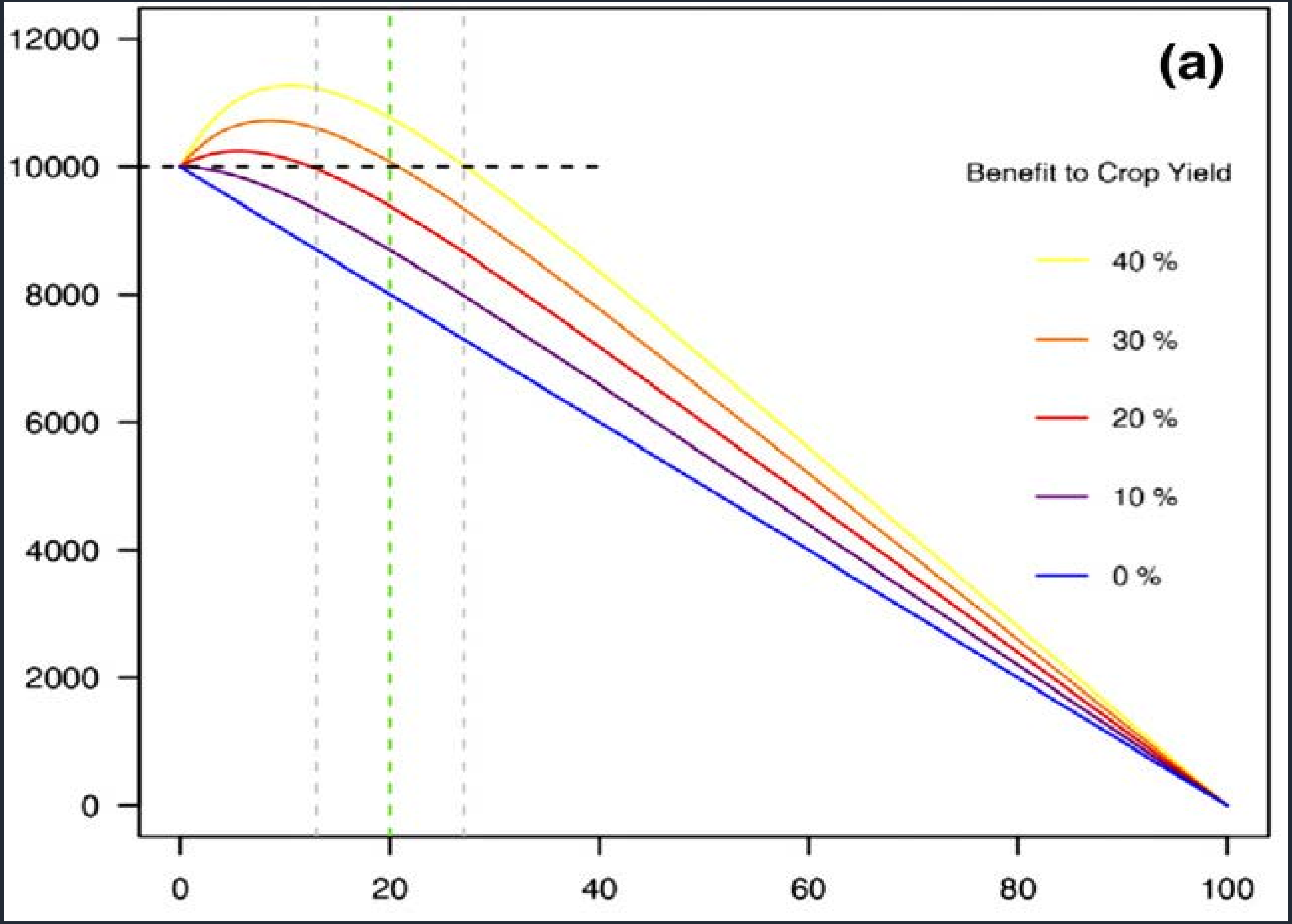
| Crop | Region | Minimum | Central | Maximum |
|---|---|---|---|---|
| Apple | UK | 5 | 15 | 25 |
| | Europe | 1 | 10 | 25 |
| Broccoli + Cauliflower | UK | 3 | 12 | 20 |
| | Europe | 3 | 12 | 20 |
| Cabbage | UK | 8 | 22 | 40 |
| | Europe | 8 | 22 | 40 |
| Carrot | UK | 24 | 31 | 50 |
| | Europe | 10 | 23 | 50 |
| Lettuce | UK | 5 | 26 | 50 |
| | Europe | 5 | 24 | 50 |
| Onion | UK | 9 | 15 | 20 |
| | Europe | 8 | 17 | 33 |
| Pear | UK | 10 | 11 | 12 |
| | Europe | 10 | 11 | 12 |
| Potato | UK | 3 | 19 | 40 |
| | Europe | 3 | 14 | 40 |

Loss factor (LF) ranges (in percent) and sources for fresh fruit and vegetables in the UK and European Economic Area (EEA).

Porter, S. D., et al. (2018). Journal of Cleaner Production 201: 869-878.

Adapted from Garibaldi, L. A., et al. (2021). "Working landscapes need at least 20% native habitat." Conservation Letters 14(2):.

# Land use efficiency

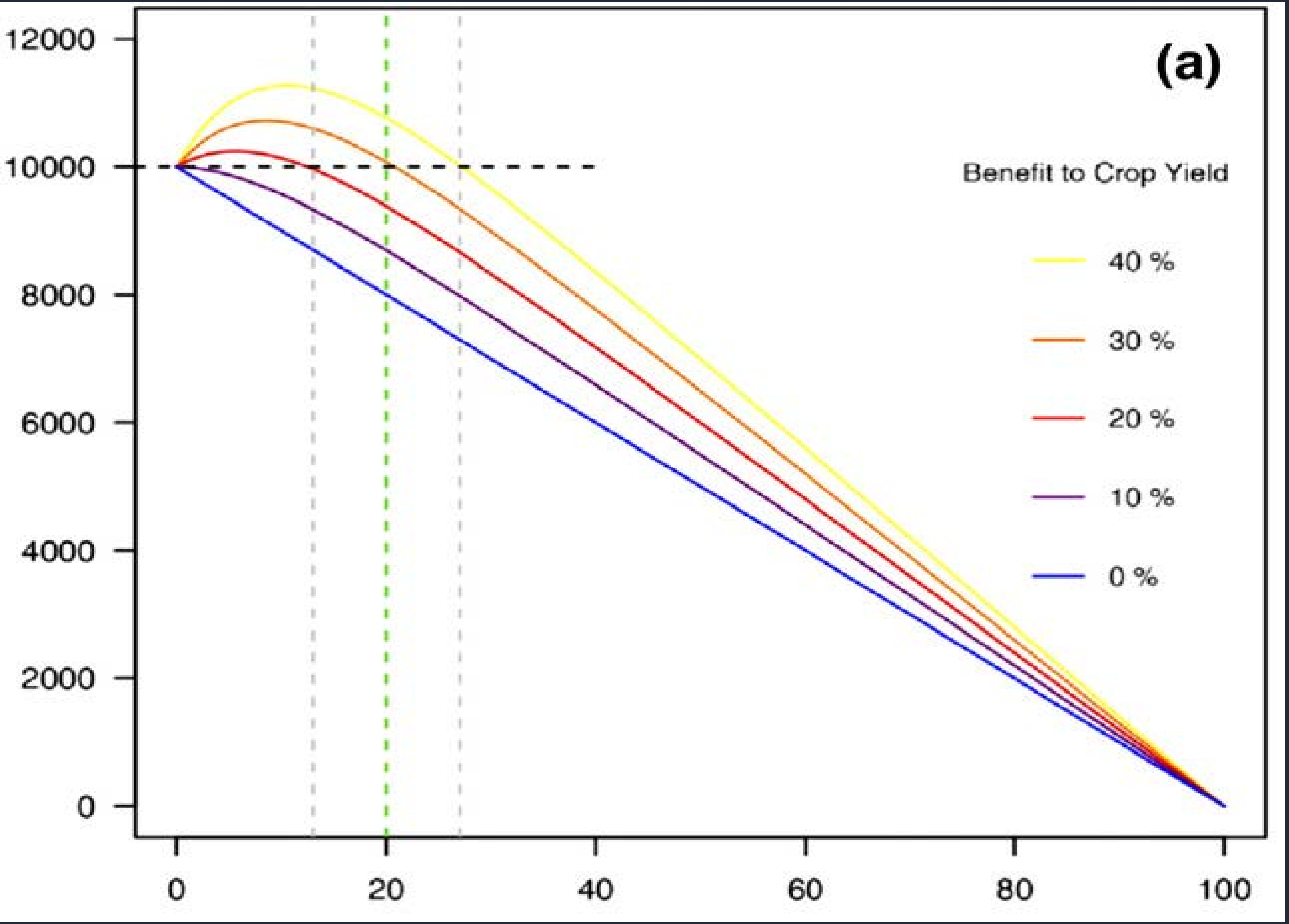



Production (Kg)

Semi natural habitat (%)

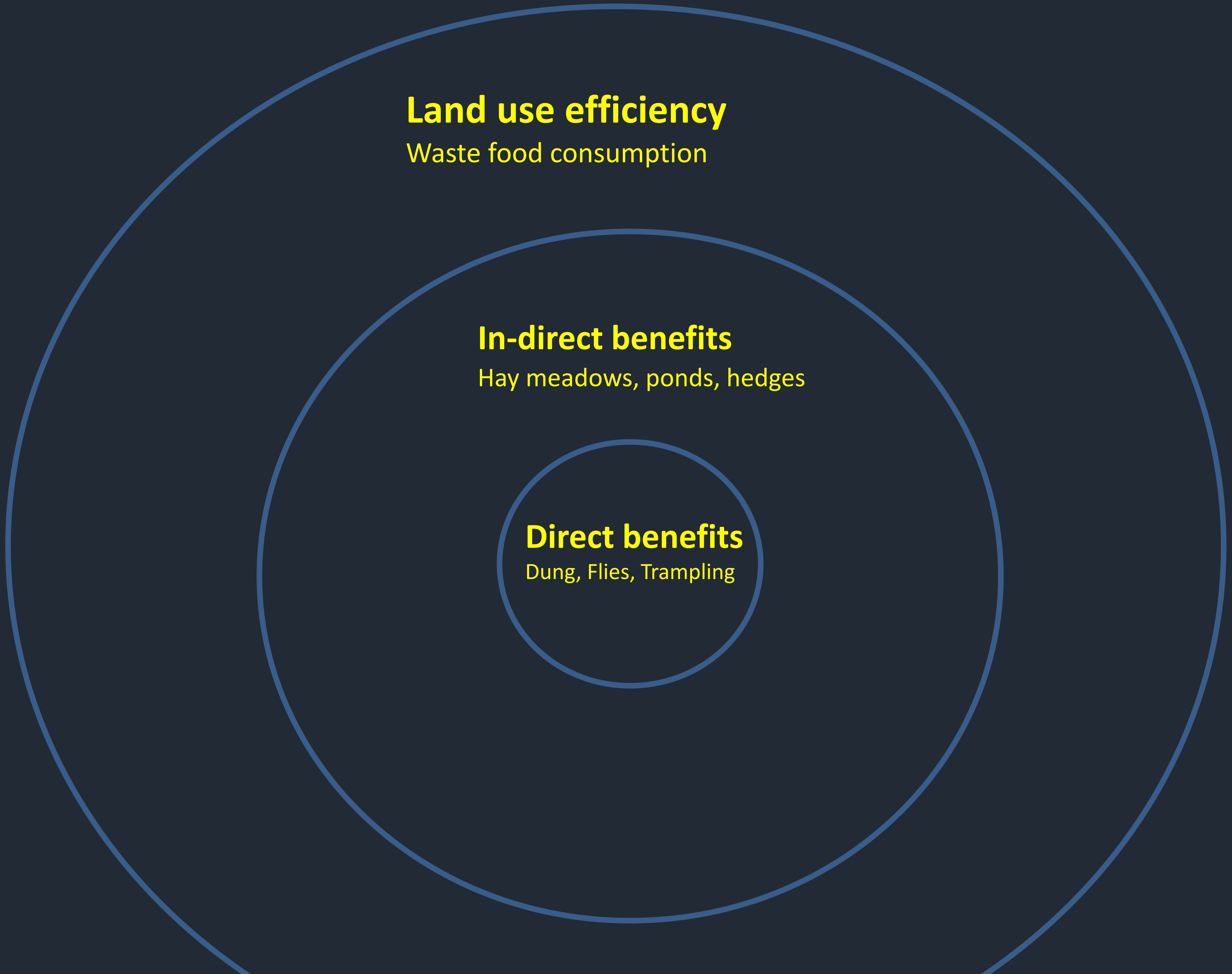
Adapted from Garibaldi, L. A., et al. (2021). "Working landscapes need at least 20% native habitat." Conservation Letters 14(2):.

# Land use efficiency




People fed

Semi natural habitat (%)




Fun: 2
Function: 5

Meat per person per yr if we only produce biodiversity supporting livestock

$1.2\ kg\ yr^{-1}$

# With thanks to

Beth Bridge, UoE and SRUC

Dr. Barbara Smith, CAWR and Central St Martins

# Conclusions

- Livestock have a role in supporting biodiversity
- There is no objective route to determining which, and what, biodiversity we need, and consequently of which, and what, livestock we need to support it
- Approximately 110 adult cows required to support a single colony of greater horseshoe bats - of **0.16%** of land
- 5% of lowland area to livestock gives approximately 1.2kg beef yr-1

THE UNIVERSITY of EDINBURGH
The Royal (Dick) School
of Veterinary Studies

Global Agriculture and
Food Systems

# The Future of Livestock in Global Food Systems

Symposium
2025

# Table Discussions

- Introduce yourselves
- Reflect on a new thing you learned, any surprises, any gaps?
- Agree on one or two high level questions for one of the speakers or for the whole panel

- Make sure someone captures some notes on the flipchart

# Advances in livestock science and technologies enhances projections of climate change impacts

Masoud Ghaderi Zefreh

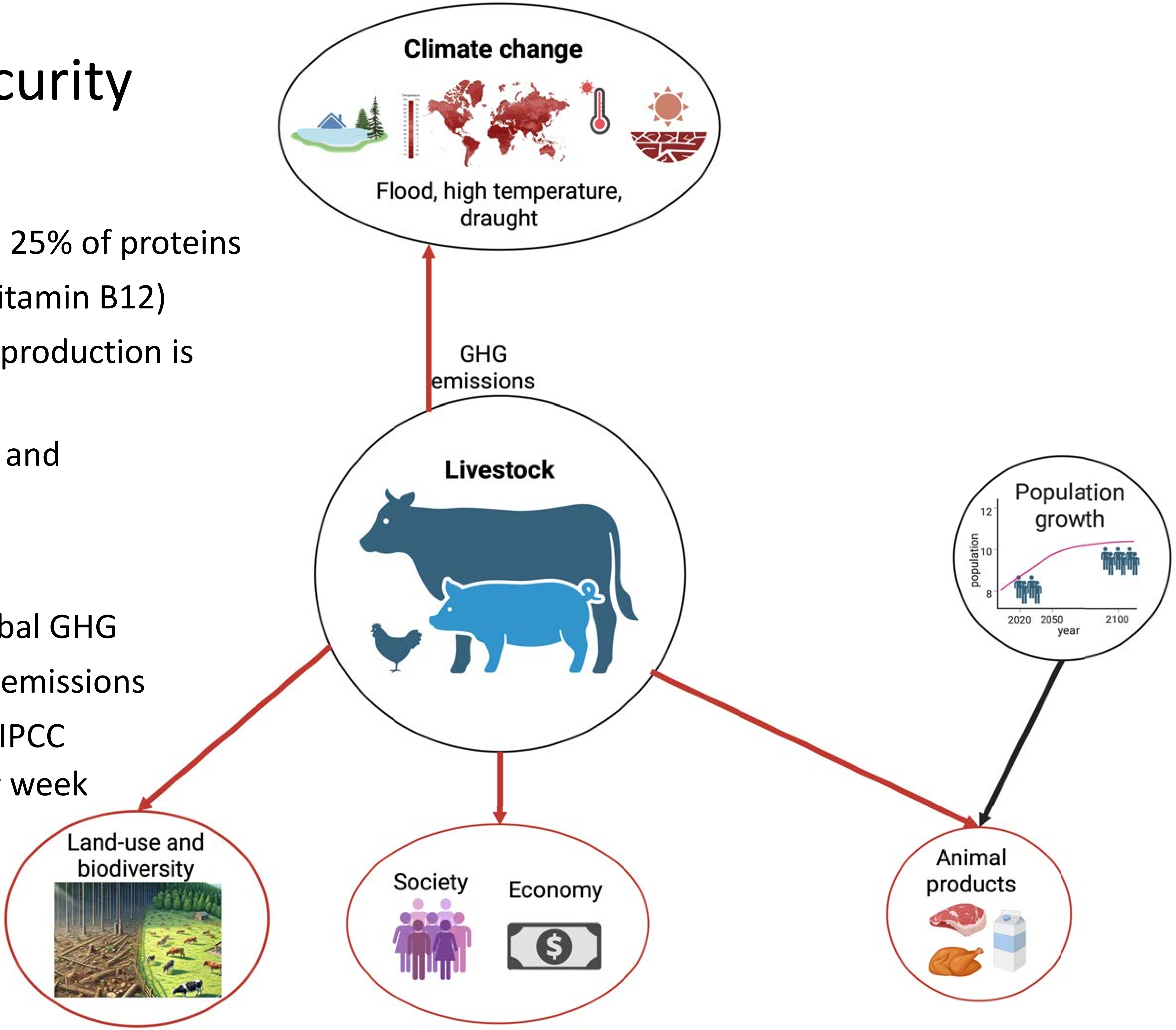
The Future of Livestock in Global Food Systems

GAAF Symposium - 2025

Biotechnology and Biological Sciences Research Council

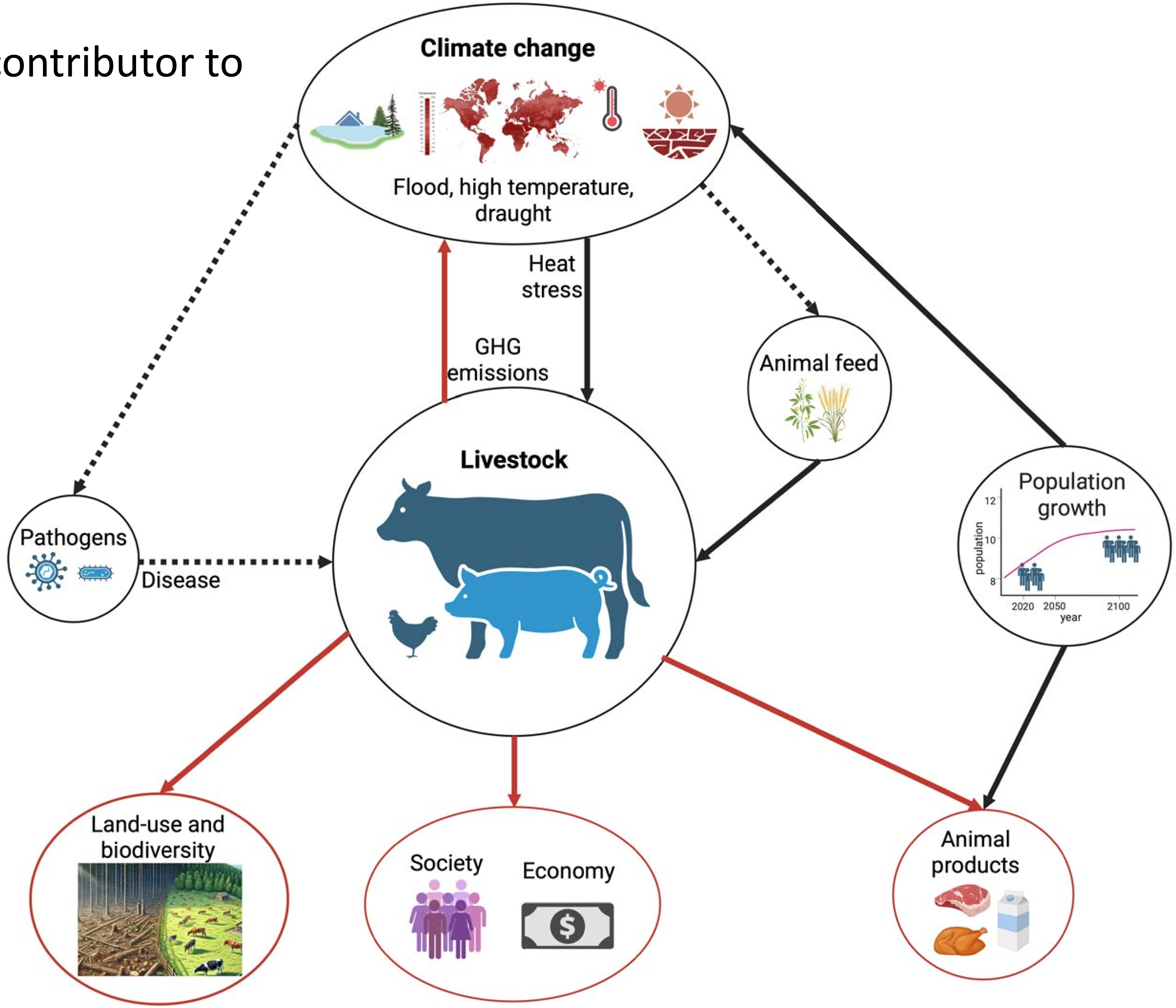
# Livestock and food security

- Ongoing Importance
  - Provides 18% of global calories and 25% of proteins
  - Essential for micronutrients (e.g., vitamin B12)
  - Supports food security where crop production is limited
  - Fundamental for low-income areas and marginal habitats
- Environmental Concerns
  - Livestock contributes to 25% of global GHG
  - Is responsible for 75% of ammonia emissions
  - Consumption must be moderated: IPCC recommends one meat portion per week
- Future Demand Pressures
  - expected to surge by up to 56% by 2050 (population + GDP growth)



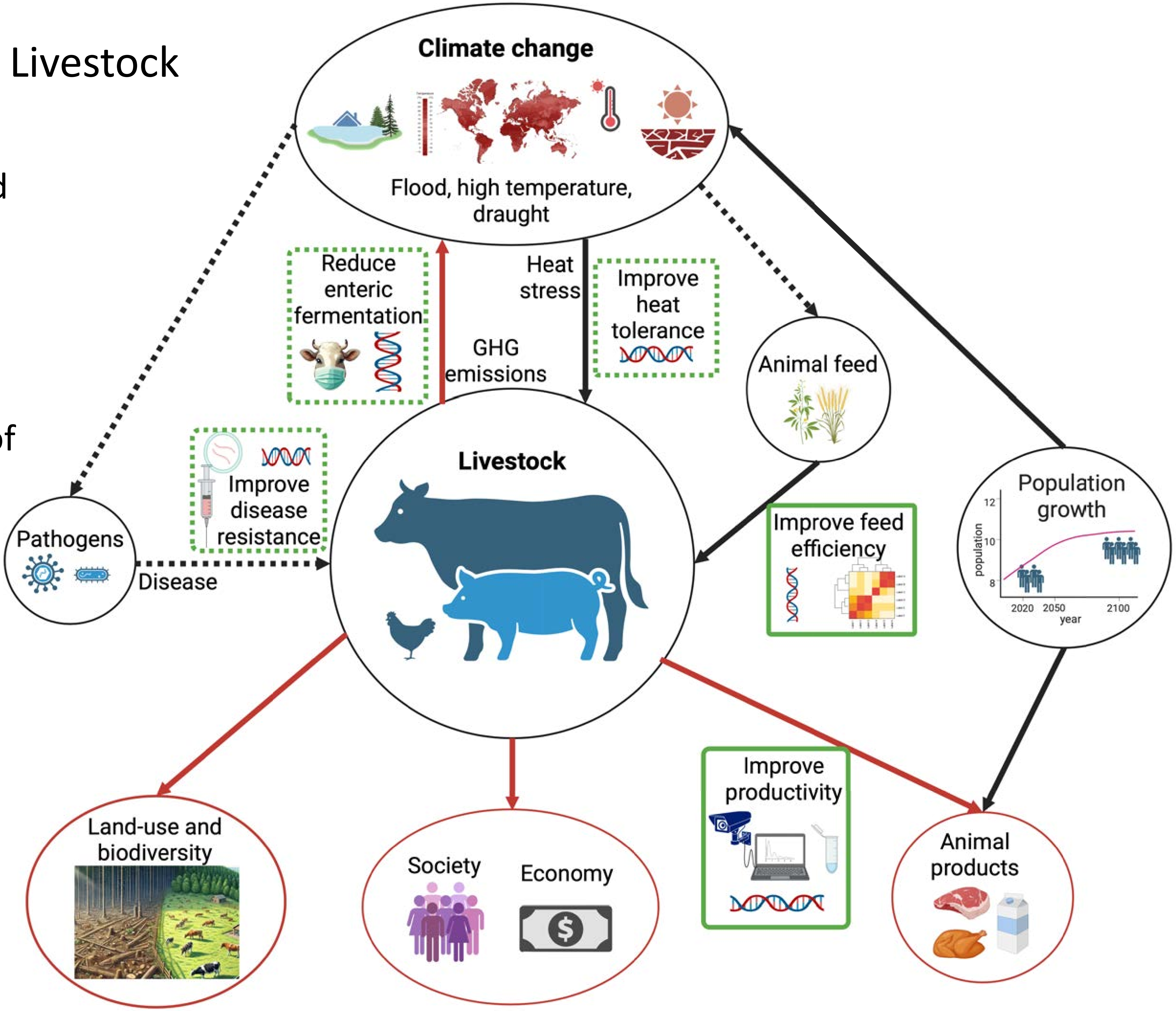
# Livestock as a victim and a contributor to climate change (CC)

- Direct effect of CC
  - Heat stress → metabolism, feed intake, production, and reproduction
- Indirect
  - Draught → feed and water
  - Extreme weather → disease
  - Roughly 20% of livestock production is lost annually to diseases



# The Need for Climate-Smart Livestock Production

- Advances in livestock science and technology are crucial for mitigation and adaptation in addressing climate change
- However, the wider implication of the new developments are not known
- The impact of such technological advances can be assessed via Economy Society Environment (ESE) models

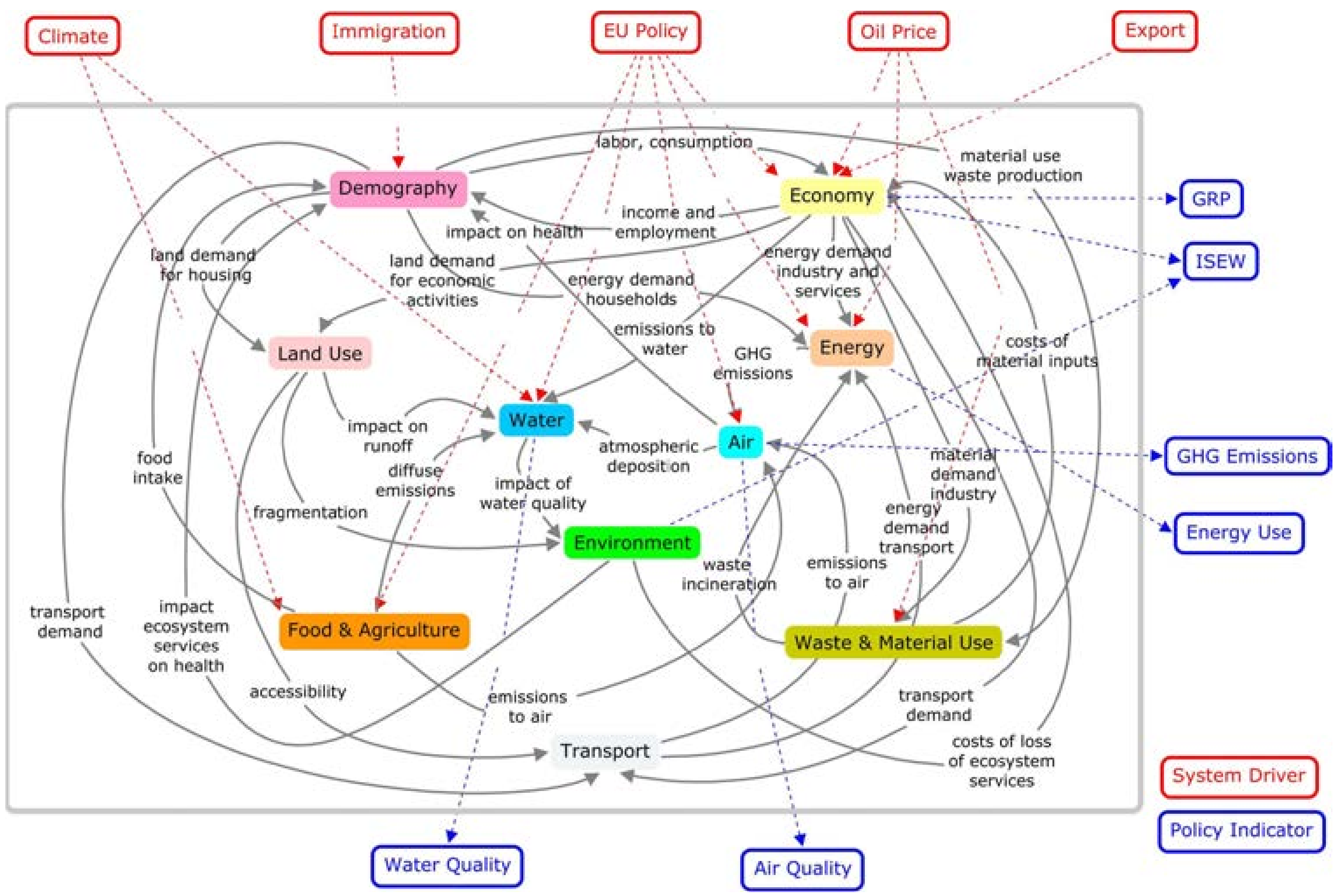


# Economy-Society-Environment (ESE) models and advances in livestock science and technology

- ESE models are tools that combine knowledge from multiple discipline to tackle complex issues like climate change

- ESE models are used to inform policies and provide recommendations for consumers

- Current ESE models do not account for recent advances and already implemented technology in livestock production




- Proposed perspective:

Better integration of recent livestock innovations into ESE models is critical for more accurate projections on global food security and socio-economics.

ROSLIN

# Case Study

Assessing global impacts of heat stress and genomic selection in 2050

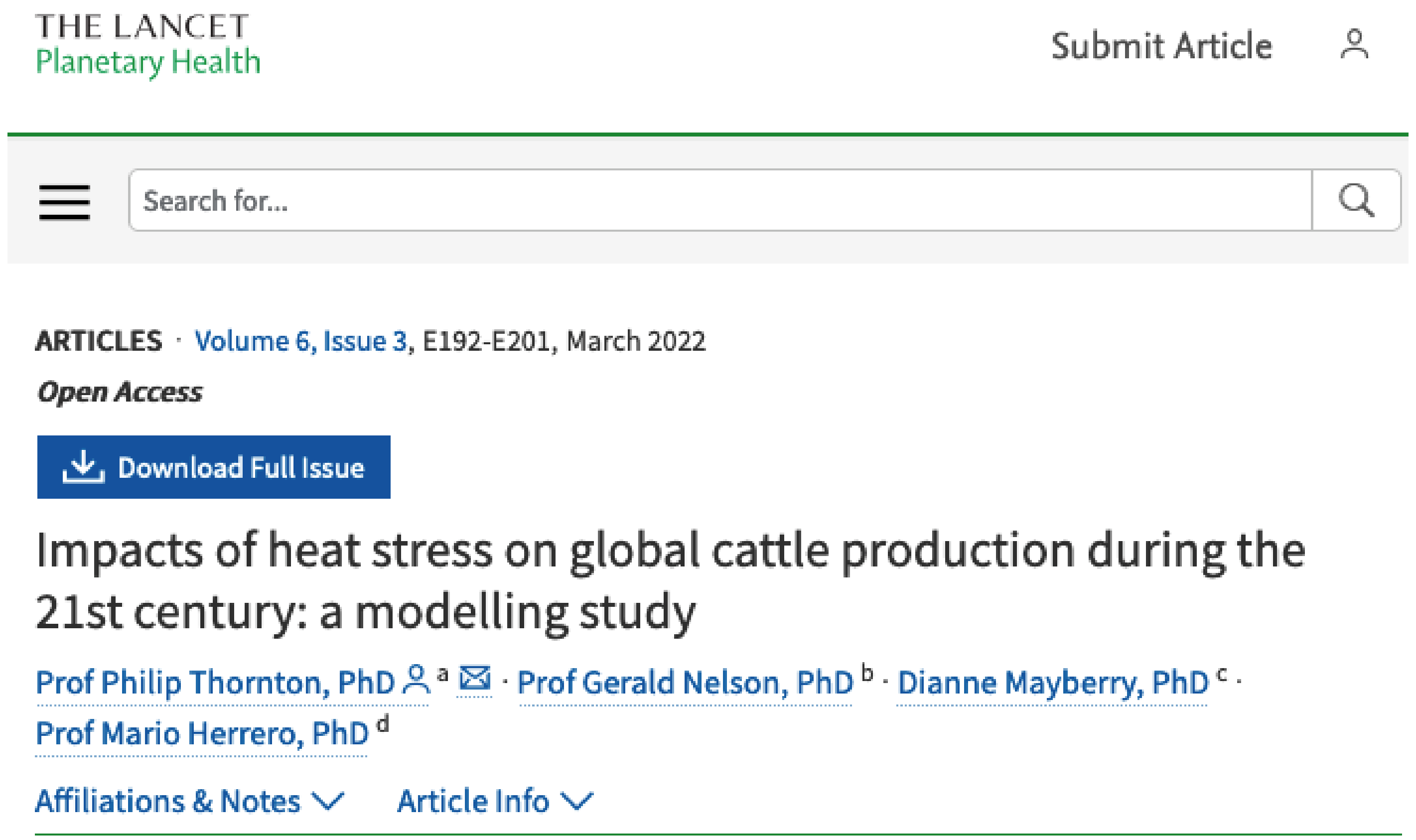
# The effect of heat stress on livestock

- For cattle, the production may be reduced by up to 5% only due to heat stress

- GHG emission from cattle may reduce by up to 2% due to lower feed-intake

- The effect of heat stress is likely underestimated

- To include
  - + pigs, broiler chickens, layer chickens, sheep and goat
  - + feed conversion ratio (efficiency) change of animals under heat stress


THE LANCET
Planetary Health
Submit Article

Search for...

ARTICLES · Volume 6, Issue 3, E192-E201, March 2022
*Open Access*

Download Full Issue

Impacts of heat stress on global cattle production during the 21st century: a modelling study

Prof Philip Thornton, PhD [a] · Prof Gerald Nelson, PhD [b] · Dianne Mayberry, PhD [c] · Prof Mario Herrero, PhD [d]

Affiliations & Notes   Article Info

# Production and efficiency drop by heat stress

- Heat stress impact is measured by combining Temperature and Humidity (THI)
- On average, with the increase of THI, animals' productivity and efficiency drop

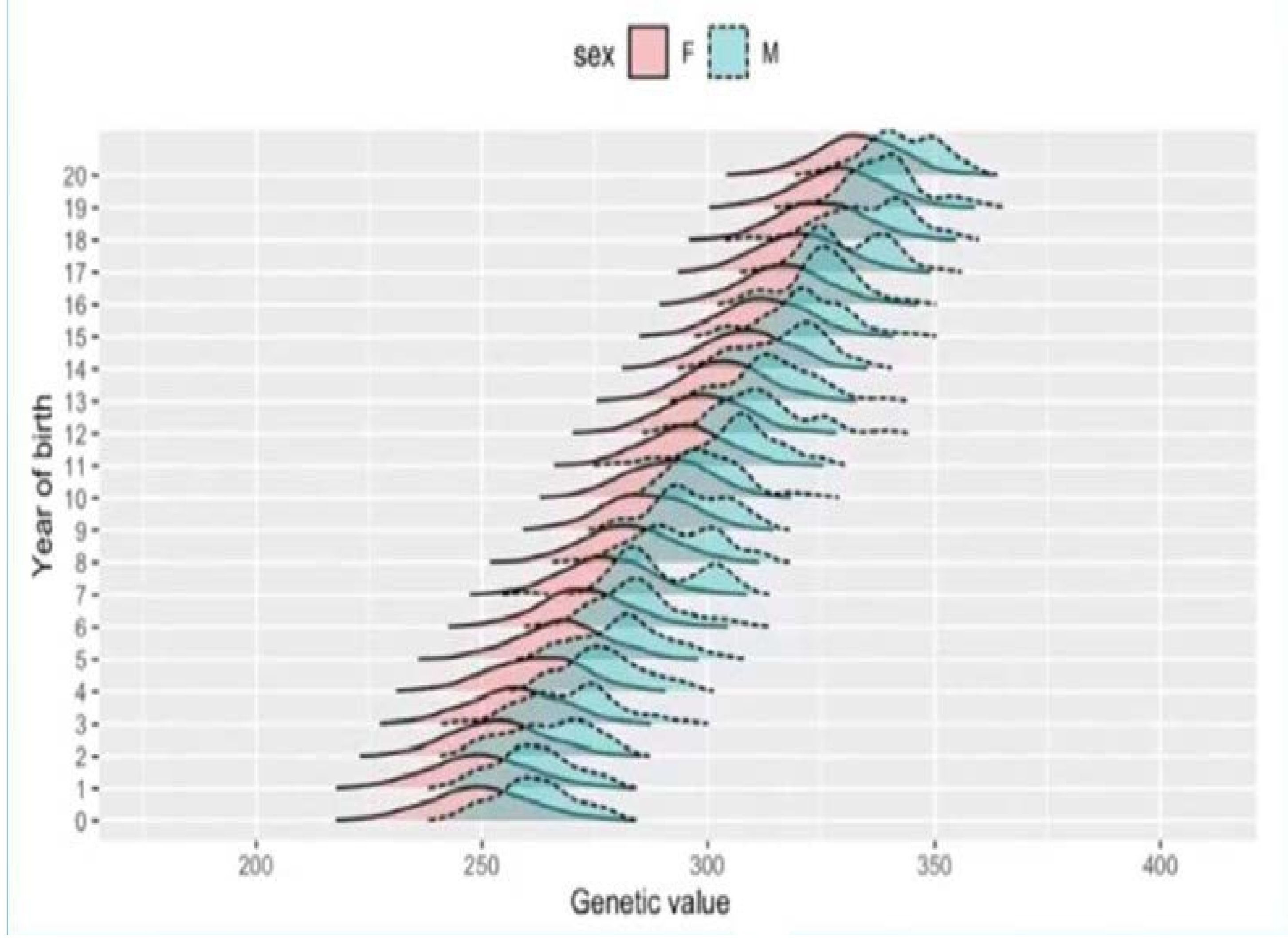
| Sector | Dairy cattle | Dairy cattle | Beef cattle | Beef cattle | Broiler chicken | Broiler chicken | Layer chicken | Sheep / goat | Sheep / goat | Pig | Pig |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Trait | milk | FCR | body weight | FCR | body weight | FCR | egg weight | body weight | FCR | body weight | FCR |
| Change in trait (%) / THI | -2.0 | 0.1 | -2.3 | 0.0 | -1.8 | 1.4 | -1.3 | -1.0 | 1.5 | -2.9 | 0.0 |

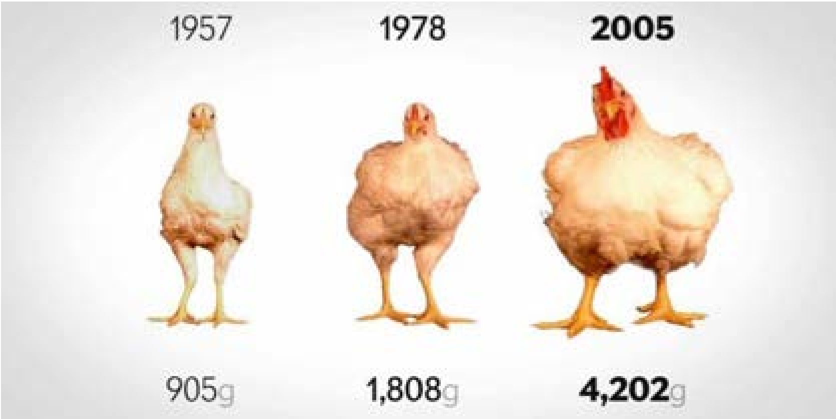
- CMIP6 climate data were used to calculate temperature and humidity projections

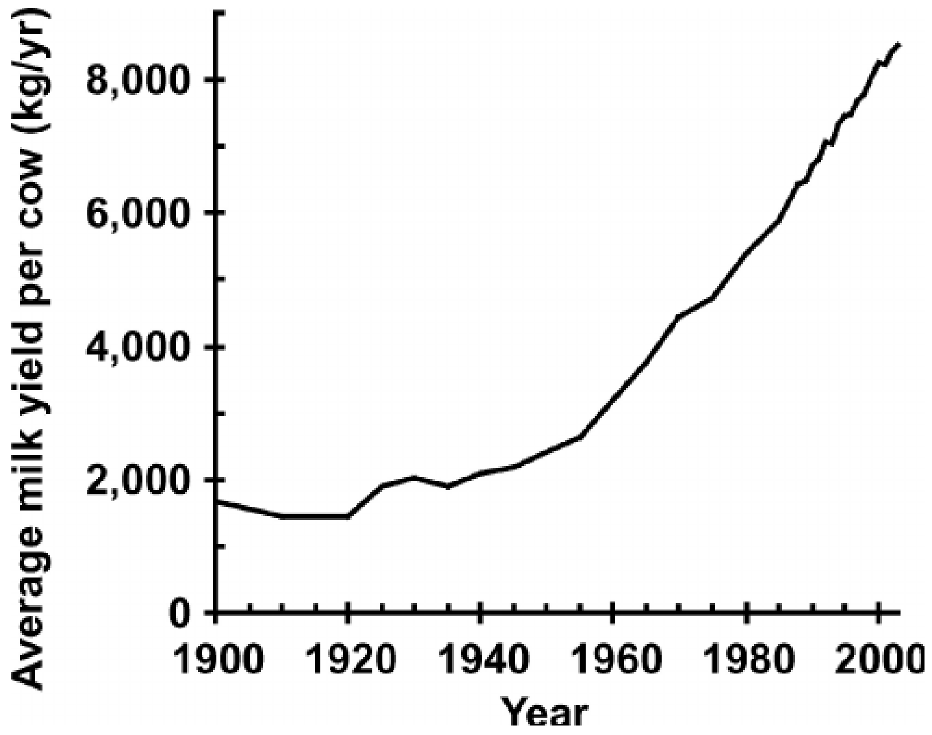
ROSLIN

# Genomic selection has revolutionised breeding

Conventional method: increase in the performance over time




Breeding is

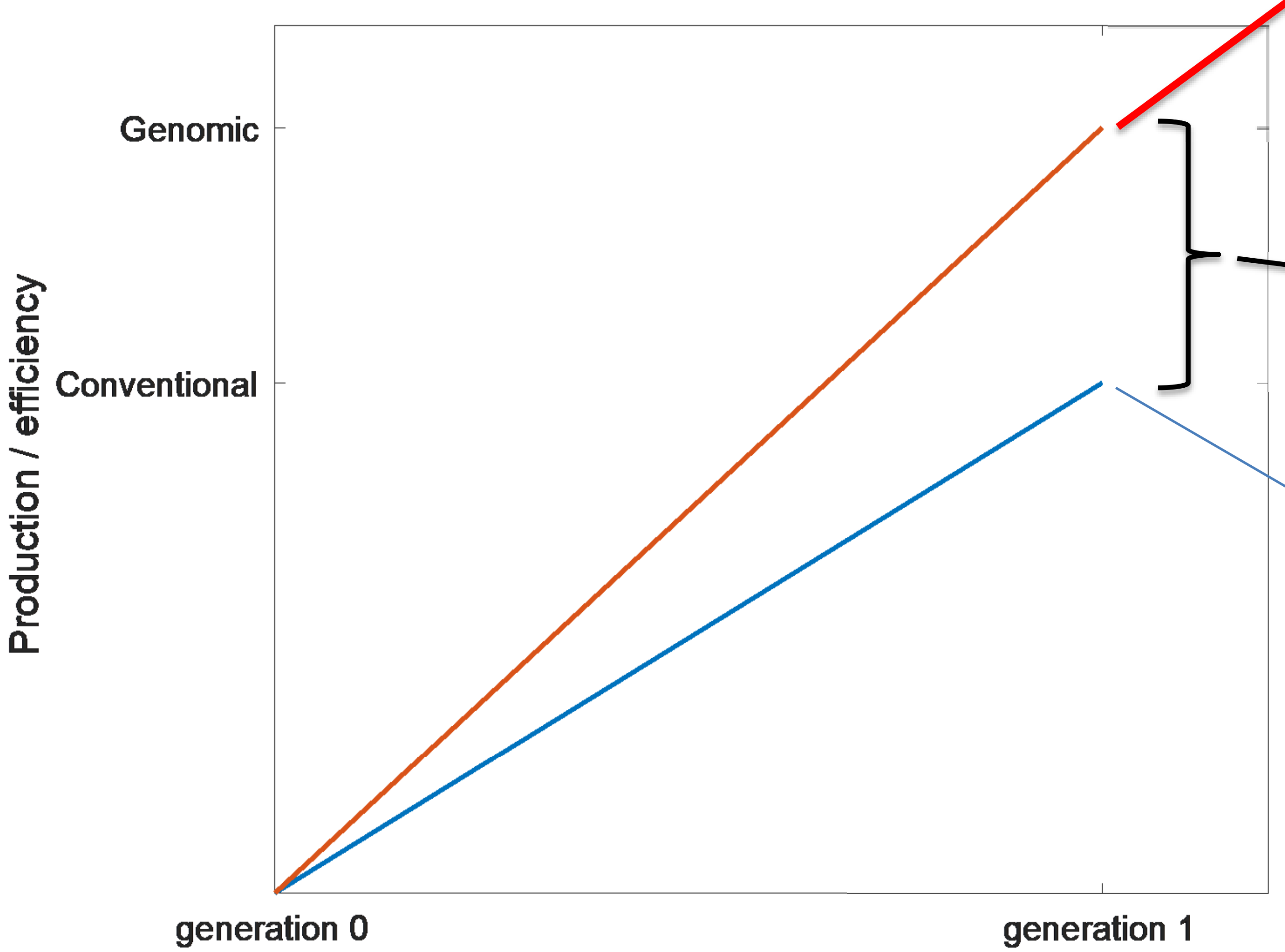
- Permanent
- Incremental
- Worldwide
- Has minimal side effects
- Genomic breeding is becoming the standard methodology worldwide

New genomic prediction

With DNA markers data we can now select for desirable traits more effectively

ROSLIN

# How contribution of genomic was calculated




Genomic selection improves accuracy of genetic merit for a trait relative to conventional method by $y$

+ Breeders' Equation

The extra gain from genomic:

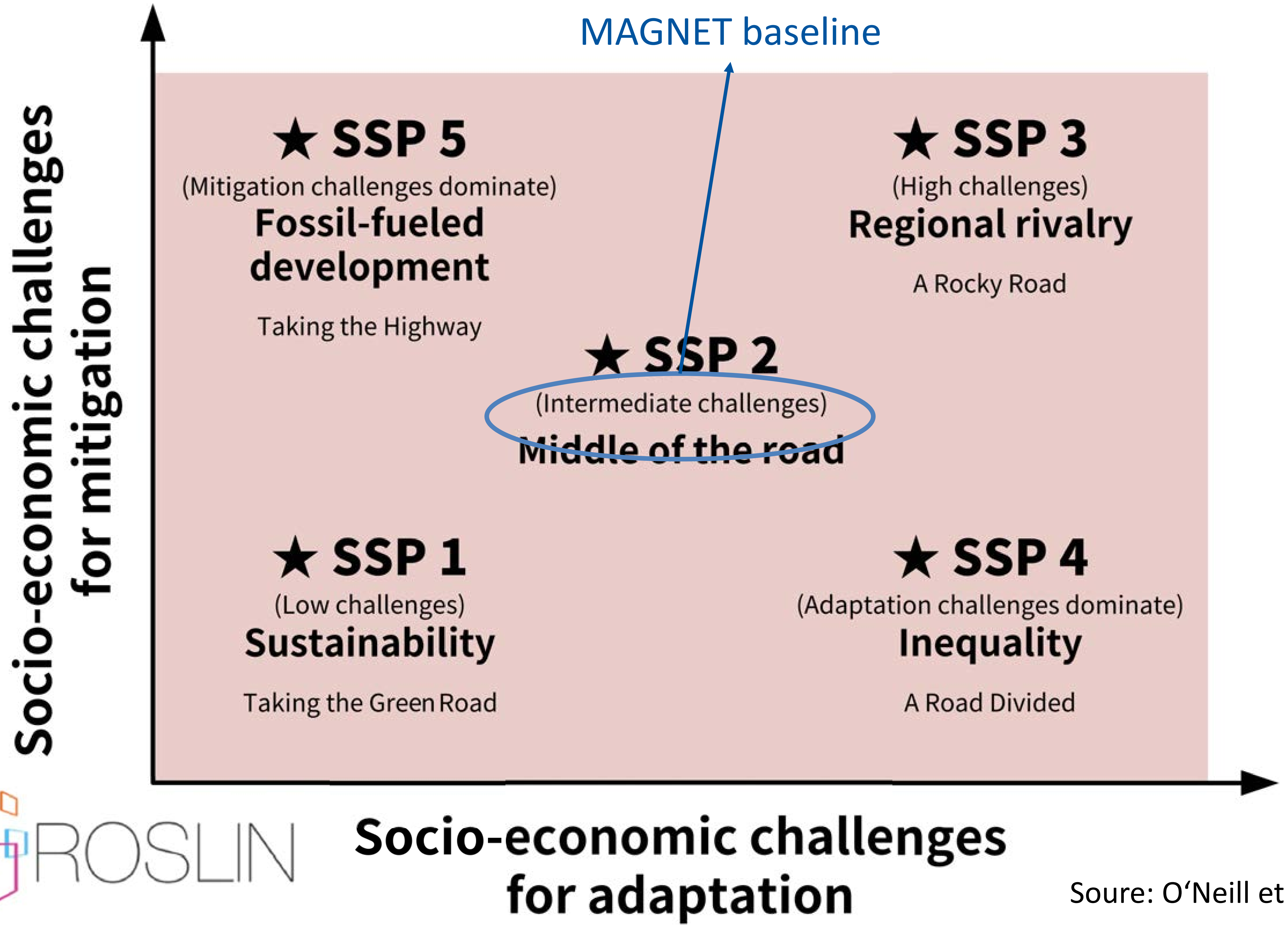
$$\frac{x\,y}{1+x}$$

Conventional method improves a trait by $x$

| Sector | Dairy cattle | Beef | Beef | Chicken | Chicken | Chicken | Sheep / Goat | Sheep / Goat | Pig | Pig |
|---|---|---|---|---|---|---|---|---|---|---|
| **Trait** | Milk yield | Body weight | FCR | FCR | Egg | Body weight | Body weight | FCR | Body weight | FCR |
| **change (%) by 2050** | 33.2 | 7.3 | -5.2 | -23.3 | 9.8 | 5.8 | 9.8 | -2.7 | 10.2 | -0.2 |

# The ESE model and the baseline used

- The contextual Scenario: IPCC-based Socio-Economic Pathways (SSPs)




Soure: O'Neill et al, 2012

MAGNET
Modular Applied GeNeral Equilibrium Tool
Wageningen Economic Research

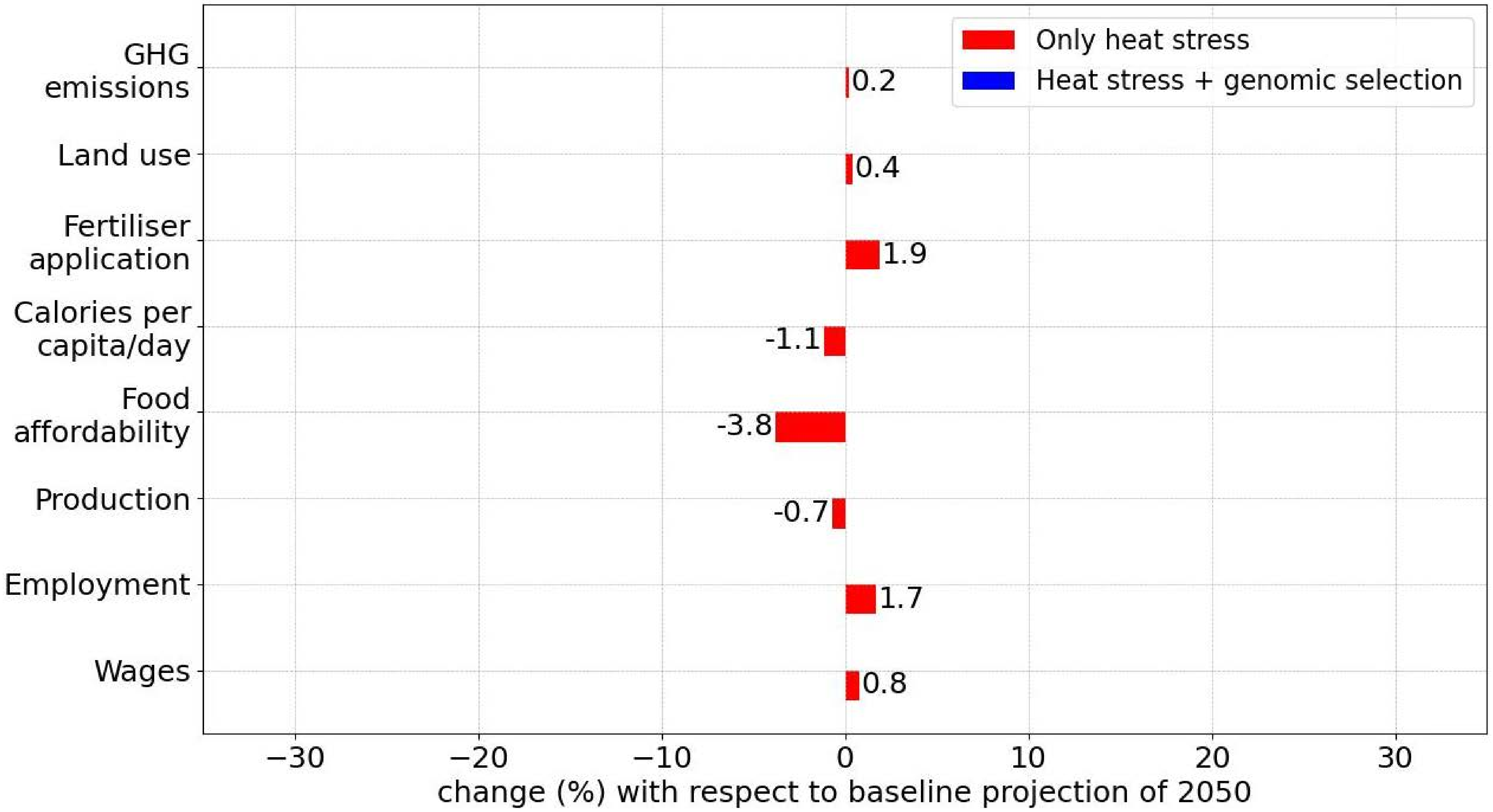
Used by EU and Scotland to assess long term impacts

Why SSP2

- World-wide adoption of genomic selection on only the two traits production and efficiency is a 'middle-of-road' scenario
- SSP2 narrative mirrors gradual shift seen historically – genomic is becoming the new standard

# Heat stress changes baseline projections

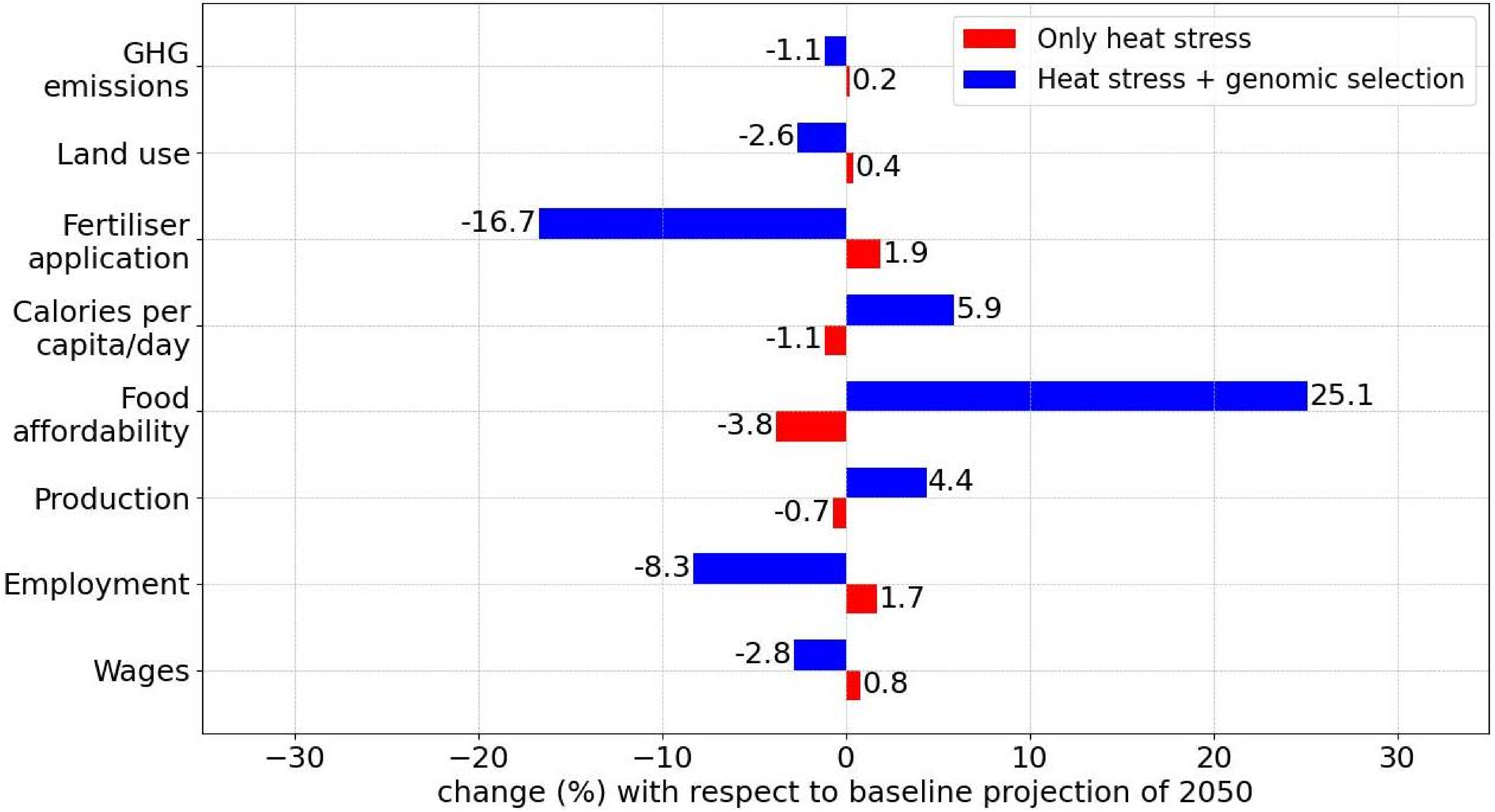
- Scenario 1: Heat stress is accounted but genomic breeding is not considered




ROSLIN

# Heat stress changes baseline projections
# Genomic selection can offset and potentially reverse the (direct) effect of heat stress

- Scenario 1: Heat stress is accounted but genomic breeding is not considered
- Scenario 2: Both heat stress and genomic breeding are accounted for.



# Limitations

- Genomic breeding can potentially offset the direct negative consequence of heat stress but not climate change
- Globally uniform impact of heat stress / improvement in genomic
- Several simplifying assumptions could lead to understatement of heat stress.
  - Example: Fertility / reproduction decrease , disease , …
- Other assumptions may underestimate the impact of advances in technology.
  - Example: Precision livestock farming, breeding for complex traits (e.g., disease resilience), …

ROSLIN

# Takeaways

- Livestock production needs to take measures for adaptation and mitigation to remain sustainable
- Heat stress changes projections from ESE/macroeconomic models ; genomic breeding can mitigate the consequences of heat stress
- Current advances in livestock science and technology may be the answer but need to be assessed using global environment-society-economy models
- Such assessments help to prioritise resource allocation for development of each technology
- Integration of the new advances requires interdisciplinary collaboration

ROSLIN

ROSLIN

THE UNIVERSITY of EDINBURGH
Royal (Dick) School of Veterinary Studies

# Acknowledgements


## Roslin Institute

Andrea Doeschl-Wilson

Ricardo Pong-Wong

## University of Stirling

Nils Bunnefeld

## Wageningen Economic Research

Marcos E. Dominguez Viera

Saeed Moghayer

Zuzana Smeets Kristkova

Willem-Jan van Zeist

## Czech University of Life Sciences

Markus Dettenhoffer

UKRI Biotechnology and Biological Sciences Research Council

Funded by the European Union

This project has received funding from the European Union's HORIZON-CL6-2022 research and Innovation programme under grant agreement N◦101084201.

Eco Ready


THE UNIVERSITY of EDINBURGH
The Royal (Dick) School
of Veterinary Studies
Global Agriculture and
Food Systems
Symposium
2025
The Future of
Livestock in
Global Food
Systems

# Table Discussions

- Introduce yourselves
- Reflect on a new thing you learned, any surprises, any gaps?
- Agree on one or two high level questions for one of the speakers or for the whole panel

- Make sure someone captures some notes on the flipchart